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Analyzing commercial grape farm efficiency in Armavir region (Armenia) by using two-stage empirical approach

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Abstract. The purpose of this paper is to provide an empirical assessment of the economic efficiency of grape-producing farms in Armenia. Upon reviewing various field-related studies the frontier analysis was singled out as a methodological base of this study. More specifically two-stage empirical analysis was performed, which includes the measurement of efficiency levels of grape farms by implementing the DEA technique and then assessing the determinants of obtained efficiency scores by performing Tobit modeling. To obtain necessary data, 365 grape farms from the Armavir region were surveyed. The main findings of this paper suggest that the average efficiency score for grape farms is 0.72, and there is room for improvement in the economic performance of farms with 28%. The main determinants of farm efficiency were cultivated grape varieties, farm size, and selling prices of grapes. The obtained results mainly support the findings of similar studies carried out for various viticulture regions across the world. This study provides some methodology bases for further expansion of similar studies both in terms of including the other Armenian viticulture regions and different years to explore the changes in the efficiency of grape farms over time. This article provides a base of knowledge for policymakers, scholars, researchers, investors, and credit companies for their decision-making processes and other purposes.

Keywords: Viticulture, grape farms, efficiency analysis, data envelopment analyses (DEA), tobit modeling, Armavir region, the Republic of Armenia

1. Introduction

According to the data of the World Bank, the Republic of Armenia (RA) is among the developing countries with above-average incomes, the trade balance of which is negative (a relatively small number of products are exported from the Republic of Armenia than imported). Fresh agricultural products and products obtained from their processing are among the few product groups that are exported. In particular, fresh and dried grapes, Armenian brandy, and wines are considered one of Armenia's business cards in foreign markets. In 2021 brandy had the second highest customs value in Armenian exports, while the products of alcoholic beverages from grape raw materials are products with comparative advantages in international trade [1].

Viticulture is one of the oldest branches of the whole Armenian economy dating back to 6000 years,[1] and it is one of the relatively profitable branches of the Armenian agriculture sector providing 53.1% (2015) and 48.1% (2020) of profitability for the whole sector [2]. Also, viticulture is relatively labor-intensive, which re-

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[1]Source: https://www.nationalgeographic.com/culture/article/110111-oldest-wine-press-making-winery-armenia-science-ucla, last accessed 24/02/2023.

quires higher levels of hand labor usage and provides high labor demand in rural areas, contributing to the alleviation of unemployment in rural areas [3]. Studies show that labor costs represent nearly 60% of annual variable costs for wine grape producers [4].

These preconditions further highlight the importance of sustainable development of Armenian viticulture in the context of solving regional issues, regional socio-economic divide, the problem of unemployment, and unequal income distribution in rural areas. In addition, the development of wine and brandy industries depends on the state of development of viticulture.

Grape growing regions in the Republic of Armenia are Ararat, Armavir, Aragatsotn, Kotayk, Lori, Tavush, Vayots Dzor, Syunik, and Yerevan regions [5], the largest role of which has Armavir region with the share of 43.5% of total vineyards. In 2021 the total area of vineyards in the Republic of Armenia consisted of 16524 ha and the gross grape harvest was 237059 tons. 74.5% of vineyards are technical grape varieties (used for wine, brandy, and cognac production), 17.5% are table grape varieties and 8% are universal varieties, which indicates that the lion's share of Armenian grapes is cultivated for the production of alcoholic beverages. In 2017 the number of grape-producing farms was 66591 with an average size of 0.23–0.50 hectares.[2] Many researchers point out the small size of Armenian grape-growing farms as a disadvantage as it cripples the production potential of economic units and prevents them from scoring high efficiency. Despite qualitative assessments of this situation from different researchers, there are no empirical studies examining the relationships between farm sizes and farm efficiency in Armenian viticulture.

Some Armenian researchers based their studies on an econometric assessment of the relationships between different production factors and viticulture development in Armenia [6] and concluded that the production-related factors (the changes in the prices of production means, machinery, resources, etc.) do not have a significant impact on the development of viticulture and observed dynamics are mostly due to the influence of the other, predominant factors. That predominant factor is revealed to be the selling prices of grapes: the positive changes in price level lead to an increase in gross grape harvest and vineyard areas, and according to carried econometric regression analyses when price increases with 1 AMD per kg then 3 years later the gross grape harvest will grow with 1256596 tons, and vineyard areas will increase with 30207 hectares in 2 years [1]. A similar study was carried out to examine the impact of gross grape harvest on the production volumes of brandy, wine, and champagne. The interdependence of those indicators has been presented with the help of the dynamic regression models with lag distribution and the results were as follows: gross grape harvest has a significant and positive impact on the production volumes of brandy 6.7 years later, in the case of wine 5.6 years later and in case of champagne 5.8 years later [7].

Sadly, existing studies examine viticulture in the periscope of the whole sector neglecting the small individual farms operating in the field of viticulture. These production units must be closely studied because their collective activities mark the main directions of further development of viticulture. In this context, the main target of the studies must be the measurement of the efficiency of grape-growing farms and the evaluation of the impact of different internal and external factors on that efficiency level. Obtained results can be crucial for policymakers, investors, and other entities of the private sector during their decision-making processes and strategic planning. The comprehensive study of grape farms' efficiency will reveal the best practices, methods, distribution of resources, etc. It will allow us to reveal the unused potential, if there is any, and highlight the main directions of possible improvement of efficiency. The examination of technical efficiency and its different determinants provides valuable insights into the causes of low productivity of farms which could help policymakers in designing development policies [8].

Considering all the above-mentioned ideas, the main purpose of this study is to measure the efficiency of grape farms in the Armavir region of the Republic of Armenia and assess the impact of different determinants on the efficiency level of grape farms. The results of this study will contribute to existing foreign literature, enrich the results of different studies of grape farm efficiency measurement and at the same time keep its originality and innovative approach.

2. Literature review

There is a rich literature in the field of empirical estimation and measurement of efficiency levels of firms both in the agriculture sector and wine sector. Specifically, we will discuss the parametric and non-parametric methodologies used for analyses of the efficiency of farms. The widely used parametric and

[2]Data was retrieved from Publications of the RA Statistical Committee, official website: https://armstat.am/en/?nid=82.

stochastic method is The Stochastic Frontier Analysis (SFA), which was introduced by Aigner, Lovell, and Schmidt [9], as well as Meeusen and van Den Broeck [10]. The non-parametric and deterministic method is Data Envelopment Analyses (DEA) developed by Charnes, Cooper, and Rhodes [11]. Various studies are using either of these methods or both for measuring the efficiency of farms in the wine sector. For example, Marta-Costa, Martinho and Santos [12] implemented both SFA and DEA for the assessment of the productive efficiency of Portuguese vineyard regions, and the results of Technical Efficiency (TE) scores were somewhat different.

In different studies, preference is given for both of these methods depending on the scientific views of researchers and the specific requirements of their studies. However, there are no unified approaches to the question of which method is better. Conradie, Cookson, And Thirtle [13] in their study of the efficiency of grape production in the Western Cape used the SFA method and concluded that output can be explained by land, labor, and machinery and that efficiency can be affected by labor quality, age and education of the farmer, location, the percentage of non-bearing vines and expenditures on electricity for irrigation. Efficiency is also dependent on farm size, so returns to scale are further investigated, showing that there are very modest returns to scale in grape production. Moreira, Troncoso, and Bravo-Ureta [14] used the SFA method for estimating the TE component of farm productivity for a sample of wine grape producers in Chile. They estimated a stochastic production frontier and obtained TE scores both for individual blocks (land units of farm) and both for farm level. The results suggest that the most influential variables, according to the partial elasticity of production, are land size (which describes the physical size of a farm) (0.62), labor (0.29), and machinery (0.10), and the average TE in farm level is 77.2%.

Tim Coelli and Orion Sanders [15] provided another example of the usage of SFA in measuring the TE of wine grape growers this time in the Murray–Darling Basin (Australia). They concluded that the average TE is estimated to be 79%, with the likelihood that many farms achieving well below this level face significant pressure in the future if grape prices do not improve. In addition, the results of their study are consistent with evidence that smaller wine grape farms are less profitable.

Tóth József and Gál Péter [16] performed a more macroeconomic approach by focusing on macroeconomic elements that affect the technical efficiency of the wine sector in the major producing countries. They estimated a Cobb-Douglas production function and technical inefficiency using the SFA method. It was revealed that the technical efficiency significantly differs between the major wine-producing Old and New World countries in favor of the latter group. The more efficient functioning of the wine sector in the New Wine World can be one of the drivers of that success, and inefficiency in Old World countries is related to some macroeconomic factors such as the development of the financial system, the quality of human capital, and per capita wine consumption.

Micael Santos, Xosé Antón Rodríguez, and Ana Marta-Costa [17] used two specifications – Cobb-Douglas and Translog for the SFA model and estimated that the average efficiency score for wine grape producers in North Portugal is 0.68/0.67. The most significant determinants in both models were Trás-os-Montes region and the production of Port wine grapes, which have a negative influence on the farm efficiency. They concluded that most variables that affect efficiency are structural and thus cannot be changed (e.g. region and specific type of wine grapes produced), whilst other determinants are difficult to modify (e.g. farm size or number of plots). Hence the producer cannot do much to improve farm efficiency from this perspective. Interestingly enough it was revealed that the small farms (predominant in the region) and the ones with a larger number of plots are the most efficient.

The DEA approach is widely used due to the advantage of not defining a functional form for the production technology. By relying on this fact Henriques, Carvalho, and Fragoso [18] used the non-parametric DEA method to measure the level of TE for a sample of wine-making farms in the Portuguese Alentejo region. They found out that an increase in farm size would improve farm efficiency, TE levels significantly depend upon specialization (the growth of TE is expected when specialization increases), the farms have a higher level of efficiency if the farmers' age is between 41 and 55 if farms are owned by farmers and managed in dry farming, and if labor use is predominantly family-based.

Brandano, Detotto and Vannini [19] studied the comparative TE of agricultural cooperatives (ACs) and conventional firms (CFs), with the data set comprising all wine-producing firms in Sardinia (Italy). For that purpose, they used the DEA method and concluded that organizational structures matter in technical efficiency and ACs are less technically efficient than CFs, on average, which means that agricultural cooperatives have no technical advantages over their conventional counterparts.

Another question regarding the efficiency analyses is defining the set of factors that influence the efficiency of farms. The factors that could influence the efficiency in dairy farms have been discussed by Mareth et al., [20] who independently conducted a systematic review of more than 400 abstracts and 85 full-text papers, but no consensus on specific efficiency determinants was recorded. So, it is up to individual researchers to determine the factors' efficiency considering the characteristics and main peculiarities of studied economic entities.

Considering reviewed literature sources and the peculiarities of Armenian viticulture this research was based on the methodology of productive efficiency assessment implemented in studies of Urso, Timpanaro, Caracciolo and Cembalo [21], and Shkodra, Dragusha, Ymeri, Ibishi, and Gashi [22].

3. Materials and methods

The efficiency assessment of grape farms and determinants of the efficiency were studied by implementing a two-stage empirical approach:

- In the first stage DEA method was performed to determine the efficiency level of grape-growing farms,
- In the second stage, Tobit regression analysis was performed which helps to determine the impact of different factors on the farms' efficiency.

DEA is a mathematical programming technique without any assumption on the data distribution and its main advantage is that allows to consider all the inputs and outputs of the economic entity at once, it has the advantage of removing the necessity to make arbitrary assumptions regarding the functional form of the frontier and the distributional form of the non-negative random variable [11].

DEA is a mathematical linear programming technique that uses a frontier approach where the frontier function is a "best practice" technique against which the efficiency of producers within the sample can be measured [22]. As Eling M. and Luhnen M. state in their work: "Frontier efficiency methodologies measure the performance of a company relative to a "best practice" frontier, which (in the case of single input/output) is determined by the most efficient companies in the industry. The efficiency score is usually standardized between 0 and 1, with the most (least) efficient firm receiving the value of 1 (0). The difference between a company's assigned value and the value of 1 can be interpreted as the company's improvement potential in terms of efficiency (see, e.g., Cooper et al. 6). Different types of efficient frontiers can be estimated. In the simplest case, a production frontier is estimated, assuming that companies minimize inputs conditional on given output levels (input-orientation) or maximize outputs conditional on given input levels (output-orientation)" [23]. The best practice frontiers can be estimated using two different methods: nonparametric and parametric approaches [24] or as can be described in other literature "There are two main approaches in efficient frontier analysis: the econometric approach and the mathematical programming approach" [23]. The econometric (parametric) approaches specify a production, cost, revenue, or profit function with a specific shape and make assumptions about the distributions of the inefficiency and error terms. One of the most common econometric frontier approach methods is "The Stochastic Frontier Approach" (SFA), which was implemented in various studies that were discussed in the "Literature review" segment. The stochastic frontier approach assumes a composed error model where inefficiencies follow an asymmetric distribution (e.g., half-normal, exponential, or gamma) and the random error term follows a symmetric distribution, usually normal. Compared with the econometric approaches, the mathematical programming approaches put significantly less structure on the specification of the efficient frontier and do not decompose the inefficiency and error terms. The most widespread mathematical programming approach is "DEA", which uses linear programming to measure the relationship of produced goods and services (outputs) to assigned resources (inputs). DEA determines the efficiency score as an optimization result [23].

The pros and cons of parametric and nonparametric approaches have been intensely debated. The parametric approaches have been criticized for relying on restrictive assumptions concerning the functional form and the distribution of random errors, for relying on input quantities as explanatory (which in all likelihood are endogenous), and for accommodating only single-output technologies.1 The nonparametric approaches have been criticized by econometricians for being deterministic approaches, lacking a well-defined data-generating process, and, more relevant, for being extremely vulnerable to outliers and measurement errors [25].

Taking into account the specifics of these two approaches, the DEA approach was deemed more suitable for this research due to the following reasons:

- DEA does not require specification of the functional form of the production function,

– DEA simultaneously utilizes multiple outputs and multiple inputs with each being stated in different units of measurement [26]. This characteristic of DEA is particularly important for this study; because input and output variables have different measurement units, and two output variables must be considered in one model simultaneously (the composition of variables and their specifications are discussed on pages 10–11).

Some variations of the DEA method have been formed and improved over time thanks to the correspondence of different researchers. Charnes, Cooper, and Rhodes [11] first proposed DEA as an evaluation tool to measure and compare the relative efficiency of DMUs. Their model yields an objective evaluation of overall efficiency and assumes constant returns to scale (CRS). The first version of their DEA model aims to minimize inputs while satisfying at least the given output levels, this is called the input-oriented model. The second type of model is called the output-oriented model which attempts to maximize outputs without requiring more of any of the observed input values. However, the CRS models have their limits during applications, because they can be used only when the return of output is constant, whereas many economic activities have external factors affecting the returns of outputs and inputs. That is why Banker, Charnes, and Cooper [27] extended early iterations of DEA models by providing variable returns to scale (VRS) versions. This VRS model distinguishes between technical and scale inefficiencies by estimating pure technical efficiency at the given scale of operation and identifying whether increasing decreasing, or constant returns to scale possibilities are present for further exploitation. VRS models too can be constructed as input-oriented or output-oriented. In our case, like the above-mentioned studies, VRS models must be applied, as grape production does not provide constant returns of scales and numerous external factors determine the size of output regardless of the input scale.

In our study the input-oriented model was chosen for the following reason: the goal of our study is to discover those effective grape farms that will help to find out how much the grape farms of the Armavir region can reduce their inputs to achieve the given outputs. For Armenian grape farms, the increase in average yield and output is not a problem, but low prices of grape and high costs are [1], then it is more important to focus more on reducing the costs instead of increasing the results. The input-oriented model helps to assess the possibilities of cost reduction and increasing cost-effectiveness.

So, the VRS input-oriented envelopment model used for this research is expressed as follows:

$$\text{Minimize } \beta j.$$
$$-Yj + Y\lambda \geqslant 0$$
$$\beta Xj - X\lambda \geqslant 0$$
$$M1\lambda = 1$$
$$\gamma \geqslant 0$$
$$\beta \in (0,1)$$

The interpretation of the DEA model for this study will be the following: for each j^{th} considered DMU, x_j will express the inputs, and y_j will represent the outputs, from these variables the matrixes of inputs (X) and outputs (Y) are formed. λ is a non-negative vector that forms the linear combinations of jth DMU. The input-oriented DEA VRS model aims to minimize the inputs, within the limits of the given outputs.

After DEA analyses the next step is Tobit modeling with the results of efficiency scores. The Tobit modeling allows us to assess the relationship between the dependent variable (in this case farms' efficiency) and various independent variables, and during that process, the determinants explaining and interpreting the observed levels of efficiency of DMUs will be distinguished.

The Tobit models are a family of statistical regression models that describe the relationship between a censored (or truncated, in an even broader sense of this family) continuous dependent variable y_i and a vector of independent variables x_i. The model was originally proposed by James Tobin (1958) to model nonnegative continuous variables with several observations taking value 0 (household expenditure) [28]. Since the efficiency scores vary between 0 and 1, they are censored, which makes the Tobit model a perfect econometric tool to continue analyzing the results of DEA efficiency scores.

The mathematical expression of the Tobit model is as follows:

$$\theta j = \alpha + Xj\beta + \varepsilon j,\ j = 1, 2, \ldots, N$$

where
θj is the efficiency value of jth DMU obtained by performing DEA,
α is the coefficient of intercept,
Xj is a matrix of explanatory, independent variables,
B is a vector of estimated coefficients,
ε_j is the stochastic error.

4. Data used

For our research, the grape growing farms of Armavir region were chosen, as this region is the main viticulture region in Armenia, where in total 19461 grape growing farms operate.[3] To obtain the necessary data for envelopment analyses sample survey was carried out because there is no official database that can give us a detailed look at economic performance and indicators of grape-growing farms.

Now let's discuss the sample size calculation that also determined the title of the article. As was mentioned earlier in the Armavir region 19461 grape growing farms operate, however only 5781 of them operate with a size of more than 0.1 ha and carry out grape production for commercial purposes. The criteria of a commercial grape farm is the size of its vineyard area. Commercial grape farms cultivate grapes in fields larger than 0.1 ha, usually separate from the houses and rural or urban settlements and those farms purchase the obtained grapes in different directions (in the market, to processing companies, to exporters, etc.) The rest of the farms that have a size of less than 0.1 ha produce grapes for their own needs and do not contribute to the formation of the total grape supply. The vineyards of those farms are located near the houses in the territory of the settlement, and sometimes contain crops other than grapes, like apricots, peaches, plums, etc. Grape cultivation is not considered an economic activity but more of a tradition in those small farms. The grape yield of those farms is consumed for household needs; it does not enter the market and does not participate in the formation of the total grape supply. There are no official statistics regarding the contribution of the small farms in the formation of grape supply. The question arises here about whether those small farms should be considered grape farms or not because the inclusion of these farms in economic studies and calculations can greatly impact the reliability of the obtained results In part this situation is the result of the flawed official statistics methodology, because The RA Statistical Committee uses outdated methodology according which all the households that grow grape vines in their near house private lands are considered as grape farms. As a result, the official number of grape farms is very large, but the reality is the lion's share of those farms do not play any economic role and do not pursue commercial interests.

Taking into account this fact in our study the number of small grape farms was excluded and for the sample size calculation, the number of commercial grape farms (medium and large sized) was taken into consideration – 5781. In this case, the sample size will be 361 with a 95% confidence level and 5% margin of error.[4] Considering the obtained number 365 surveys were carried out amongst grape-growing farms in the Armavir region.

A questionnaire of 19 questions was constructed by the authors to be used during surveys. All the 365 questionnaires were filled and provided all the necessary data for the DEA and Tobit calculations: the size of grape farms in hectares, the total production costs, the total income received from grape sales, and the average yield of grapes of a given farm in metric tons per hectare.

The input variables for the DEA model are the size of the farm (ha) and total production costs (thousand AMD), and the output variables are the total income received from grape sales (thousand AMD) and the average yield of grapes of the given farm (tons/ha). The selection of DEA output and input variables, and the variables of Tobit regression, was based:

- on the studies discussed in the "LITERATURE REVIEW" segment [14,17,18,21,22],
- on the peculiarities of grape farms of the Armavir region determined by the results of the survey Those peculiarities include production type, management style, the operation of farms, the common practices of grape cultivation in Armenia, etc.

The output variables were chosen in a way that they balance each other, because if the sole output variable was total income, then efficiency would depend on the total harvest of grapes farm and selling prices, leaving out the fact that farms can efficiently produce large amounts of harvest but because of low prices receive relatively low total incomes, which would automatically lead to low efficiency. By including the average yield as an output variable, it is assumed that the efficiency criterion for DMUs must be the maximum yield and maximum yield by the expenditure of minimal inputs. The descriptive statistics of DEA variables are presented in Table 1.

The variables of Tobit regression are following (the descriptive statistics of variables are presented in Table 2):

[3] The report "Viticulture and wine market research in Armenia" (in Armenian), The Fund for Rural Economic Development in Armenia (FREDA), Retrieved from: http://freda.am/wp-content/uploads/Final-Report-Grape-and-Wine-Final1.pdf last accessed: 15/03/2023.

[4] https://www.calculator.net/sample-size-calculator.html.

Table 1
Descriptive statistics of output and input variables of the DEA model

		Unit	Mean	Min	Max	St. Dev.
Inputs	Size	Ha	1.40	0.12	70	4.3
	Total production costs	Thousand AMD	1986.7	169	131320	7659.4
Outputs	Average yield	T/ha	22.3	0.5	42	6.3
	Total income	Thousand AMD	3891.0	153	162750	10416.6

Table 2
The descriptive statistics and frequency distribution for efficiency scores (θ_j)

Group	Number	%
1	26	7
0.9–0.99	57	16
0.8–0.89	56	15
0.7–0.79	60	16
0.6–0.69	67	18
0.5–0.59	55	15
0.4–0.49	28	8
0.3–0.39	11	3
0.2–0.29	5	1
	365	100
Max	**1.00**	
Min	**0.22**	
Mean	**0.72**	
Median	**0.72**	
St. Dev.	0.19	

Table 3
Distribution of the efficiency scores by farm size

Farm size, ha	The mean value of θ_j
0.1–0.5	0.81
0.5–1.0	0.66
1.0–2.0	0.70
2.01–5.0	0.76
5.0–10.0	0.96
10 >	0.94

– Dependent variable. Y-Efficiency score. θ,
– Independent variable 1. The gender of grape producer. X_1,
– Independent variable 2. The age of grape producer. X_2,
– Independent variable 3. The education level of grape producer. X_3, (there is a common notion that the higher the level of education the more efficient managerial processes are, which brings the following hypothesis: higher education levels of grape producers will positively affect the efficiency level of DMUs. This is a dummy variable that takes the values 0 or 1 to indicate the absence or presence of some categorical effect that may be expected to shift the outcome. In our case, the value 1 corresponds to grape producers with "Intermediate "or "Advanced" education and the value 0 to grape growers with "Less than basic" or "Basic education" (according to International Standard Classification of Education (ISCED)).[5]
– Independent variable 4. The land area of vineyards (abbreviated as the size of the vineyards).[6] X_4, To characterize the influence of this variable, the following hypothesis was put forward: the efficiency is higher in the farms with bigger vineyard sizes.
– Independent variable 5. Cultivated grape variety X_5, this variable too accepts the values 0 or 1, with value 1 corresponding to technical varieties, and value 0 corresponding to table varieties. The inclusion of this variable in the model will allow us to find out the nature of the influence of the grape variety on the efficiency factor of farms and the significance of that influence (if there is any).
– Independent variable 6. The age of vineyards. X_6,
– Independent variable 7. The selling prices of grapes. X_7.

5. Results

The results of the DEA analysis are summed in Tables 2–4. The following main results were obtained for the efficiency coefficients of grape farms:

– Out of 365, 26 farms recorded the maximum 1 value of efficiency, while the minimum value of efficiency was 0.22,
– Both the mean and median values of the efficiency score were 0.72, which means that grape-growing farms of the Armavir region can improve their efficiency scores by an average of 28% if they adjust their input use according to best practice.
– The highest average value of efficiency score (0.96) was recorded in farms with a size of 5.0–10.0 ha. In the case of farms with a size of more than 10 hectares, the average efficiency score was 0.94, only slightly inferior to the previous group. The lowest value was recorded in farms with sizes

[5] https://ilostat.ilo.org/resources/concepts-and-definitions/classification-education/.
[6] Further in the study the term "size" is used as a substitute for "land area".

Table 4
Distribution of the efficiency scores according to different farm variables

Average efficiency scores according to the age of the grape producer		
< 35	36–63	$63 >$
0.77	0.72	0.79
Average efficiency scores according to the education of grape producer		
Basic	Intermediate	Advanced
0.73	0.76	0.75
Average efficiency scores according to the cultivated grape variety		
Technical (for brandy/cognac)	Technical (for wine)	Table
0.71	0.77	0.79
Average efficiency scores according to age of vineyards		
< 15	15–32	$33 >$
0.75	0.75	0.73

of 0.5–1.0 ha. Interestingly, the average value of the efficiency in farms with a size of 0.1–0.5 ha is significantly different from that group, by being 0.80. This situation is determined by the fact that in small grape-growing farms usually the lion's share of the handwork is done by own family, which leads to a reduction of labor costs and an increase in efficiency. The analysis of the efficiency scores, according to the farm sizes, leads to the conclusion that farms with larger sizes are more efficient in grape production.

To gain a more detailed and deeper understanding of the efficiency score of grape farms the distribution of efficiency score was performed according to the age and education level of grape producers, according to age of vineyards, and the grape variety.

It was revealed that the highest efficiency level (0.79) was recorded in the farms that are owned by grape producers whose age is above 63, which means that older grape growers operate more efficiently (due to their accumulated experience), however, it must be noted, that the scores of other age groups do not vary significantly. In regards to grape growers' education level, as well as in the case of vineyards' age criterion, significant differences in efficiency scores were not recorded. The situation is quite different in the case of cultivated grape varieties: the efficiency score is its highest in table grape farms (0.89), whereas it is considerably lower in brandy varieties cultivating farms (0.71). The relationship between efficiency level and farm variables is discussed in more detail within the framework of Tobit modeling.

Before diving into the results of Tobit modeling it is important to discuss the statistical significance of the whole model and its variables. To check the significance of the variables included in the model and to determine the appropriateness of including them in the Tobit model, the Wald test was performed. With the results of this test, it became clear that two of the seven independent variables should be excluded from the model because their influence is not statistically significant and their exclusion from the model will not affect the quality of the model. Those two variables are the grape growers' education level (X_3) and the age of the vineyards (X_6).

The other five farm variables were included in the Tobit model and the significance of the overall model was assessed using the Wald test. The test results allow us to reject the null hypothesis that the variables involved in the model are not statistically significant; as a result, we can consider the Tobit model of this study statistically significant, and the obtained results to be scientifically sound and reliable.

The results of Tobit modeling are the following.

- The significance of the gender of the grape grower is the weakest compared to other factors.
- The regression coefficient of the grape producer's age is 0.002463, which means that the efficiency of the farms grows as the age of grape producers increases.
- The regression coefficient of the farm size is 0.006180, which confirms the put-forward hypothesis that the efficiency increases with the increase of the size of the farm. The obtained result is fully supported by the data in Table 3, where the highest efficiency scores were recorded in the groups with larger farm sizes.
- Among the farm variables of the Tobit model, the most significant is the cultivated grape variety with the biggest regression coefficient. According to the results of the Tobit model, the efficiency score decreases by 0.162879 points in the case of the technical grape variety. That is, farms cultivating table varieties work more efficiently, which is due to the relatively high yield and high selling price of table varieties.

Table 5
Description and summary statistics of Tobit model variables

	Unit	Mean	Max	Min	Std. Dev.
Dependent variable					
Efficiency score		0.72	1	0.22	0.19
Independent variables					
Age of grape producer		55	87	24	12.78
Size of the farm		1.4	70.0	0.1	4.3
Age of vineyards		22.4	55.0	2.0	13.2
Selling prices of grape		137.0	250.0	100.0	33.5
Gender of grape producer		1 – Male		0 – Female	
Education level of grape producer		1 – Intermediate/advanced		0 – Basic	
Cultivated grape variety		1 – Technical		0 – Table	

Table 6
Results of Tobit regression between grape farm efficiency and farm variables ($n = 365$)

	Regression coefficient		Z statistics
	b	St. Dev.	
C	0.511994***	0	5.361216
X_1	0.060192*	0.029827	2.018034
X_2	0.002463*	0.000781	3.154611
X_4	0.006180*	0.003042	2.031772
X_5	−0.162879***	0.039532	−4.120181
X_7	0.001103*	0.000430	2.5664933

$^*P < 0.05$, $^{**}P < 0.01$ and $^{***}P < 0.001$.

– The regression coefficient of sales prices is also statistically significant and its value was 0.001103. The latter states that if the selling prices of grapes increase, then the efficiency of grape farms increases.

6. Discussion

The analysis and empirical assessment of the efficiency of grape farms in the Armenian Armavir region provided somewhat identical results to similar studies of other viticulture countries and regions. The average efficiency score for grape farms of the Armavir region was 0.72, which, in comparison with Kosovo grape farms (with an average Economic Efficiency score of 0.521) or with Italian grapevine farms (where the average values of θ varied between 0.213–0.355) is relatively high. Though it must be admitted that the results of DEA must always be interpreted relative to other observed DMUs within the sample because one of the disadvantages of DEA is its inability to compare units to a theoretically defined performance level, the results are always in the context of the unit(s) with the best actual performance and do not lead to conclusions about how the best unit may be improved [29]. So, such differences between the efficiency scores of the farms of different studies do not necessarily mean that farms of the Armavir region operate more efficiently than Italian or Kosovo farms.

Perhaps one of the profound findings of this study is the fact that in the Armavir region, the size of production units positively affects its efficiency: thus, the development potential and efficiency of viticulture organizations are influenced by the size of an organization. This result is in sync with the findings of Sellers and Alampi-Sottini, who studied 723 viticulture organizations in Italy and concluded that the size of the organization has a positive effect on its economic efficiency. The results of their research showed a positive and statistically significant correlation between the size of the organization and its profitability [30]. Similar results are recorded in studies of Urso, Timpanaro, Caracciolo and Cembalo [21], Conradie, Cookson, And Thirtle [13], Moreira, Victor and Troncoso, Javier and Bravo-Ureta, Boris. [14], Tim Coelli and Orion Sanders [15], and Henriques, Carvalho, and Fragoso [18], all concluded that larger grape farms are more profitable and operate more efficiently. Interestingly enough some field studies prove the counterpoint, that farm size can negatively impact the efficiency of farms or will have a slight effect on it due to increasing costs of labor, production means, money per unit of land, or inability of family labor to cover labor demand of farms with large vineyards. Such results can be found in the works of Shkodra, Dragusha, Ymeri, Ibishi, and Gashi [22], Delord, Montaigne, and Coelho [30] and Santos, Rodriguez, and Marta-Costa [32].

In this study, it was revealed that the group of farms with the smallest size (0.1–0.5 ha) scored efficiency levels above average ($\theta = 0.81$), which is because, in small farms, the bulk of labor use is provided by family labor. These results are supported by the findings of Henriques, Carvalho, and Fragoso [18], who state that in the Portuguese Alentejo region grape farms have a higher level of efficiency if labor use is predominantly family-based. The negative impact of farm sizes on efficiency levels is supported by the findings of Shkodra, Dragusha, Ymeri, Ibishi, and Gashi [22].

The next farm variable that has a significant impact on farm efficiency is the price factor, as the obtained results once again reinforce the importance of the price factor in grape production efficiency and profitability [31,33], not only micro-level but in macro-level too price factor plays a predominant role and largely determines the development trend of Armenian viticulture [1].

The inclusion of grape producer's gender variable pursues more informational purposes; it is not that largely discussed and paid attention to. Similar is the variable of grape producers' age. The estimation of these two variables' impact on efficiency is generally useful for credit companies, and investors during the creditworthiness assessment of grape producers. Interestingly enough the findings of this study are partially supported and opposed by the findings of Urso, Timpanaro, Caracciolo and Cembalo [21], that in the case of Italian grape farms male grape producers operate more efficiently like in Armenia, whereas when the age of grape producer grows older the efficiency decreases. The situation is mainly conditioned by the differences in viticulture practices of these countries. In regards to gender, it is common that especially in Armenia men are more engaged in agriculture practices than women and it was somewhat expected that men would operate more efficiently. The case of the grape producer's age can be explained by the fact that the experience and management skills of the grape producer increase with age, as a result of which the grape farm operates more efficiently. It turns out that for the efficiency of grape production, the accumulated experience of the grape grower is more important than having a high level of education.

The specialization of grape farms has a significant impact on the efficiency of grape farms. In different studies that specialization is interpreted differently depending on the grape variety, the type of wine produced, etc. In the case of the Armavir region, it was revealed that farms that cultivate table grapes score higher efficiency levels in comparison with farms that cultivate technical varieties. This situation is conditioned by the fact that table varieties provide relatively higher average yield, and the selling prices of table varieties per kg are higher too. At the same time, the production costs do not vary significantly between table grape and technical grape production which brings us to the conclusion that under equal conditions table grape-producing farms operate more efficiently.

The results of the two-stage empirical assessment form a practical body of knowledge, that can have the following practical and policy implications:

- Since the highest efficiency is scored in the farms with a size of 5.0–10.0, then it can be assumed that the size of 5.0 ha and more is the optimal size for grape farms in the RA Armavir region. RA Ministry of Economy is implementing a state support program, that is aimed at the establishment of new vineyards, and the minimal size for the vineyards is set at 0.5 ha. Taking into account the results of this study raising that threshold uo 5,0 is justified.
- The RA Government can take into account the impact of various factors (such as gender of farmer, age of farmer, grape variety, etc.) on the efficiency of grape farms during its policymaking processes.
- Private sector companies, investors, banks, and credit companies also can use the results of this analysis during their decision-making processes. For example, investors, that want to engage in grape production, can orientate about vineyard size, or grape variety to achieve high efficiency levels. Creditors can use the results of this analysis when making a loan lending decision.

Those were the main points and results made by this study, however, it must be noted that the study is limited by the fact that it does not provide a comparison between the Armavir region and other viticulture regions of Armenia, or it does not explore the dynamics of grape farms' efficiency through time. This study provides some methodology bases for further expansion of similar studies both in terms of including the other Armenian viticulture regions and different years to explore the changes in the efficiency of grape farms over time.

It must be noted that the results of this study can not be extrapolated to other countries, as the economic, and environmental conditions vary drastically from country to country. These results can be used only for broad comparisons between countries. From the other 4 grape-growing regions the results of this particular study can be extrapolated only for the Ararat region. The Tavush, Vayots Dzor and Aragatsotn regions of RA have different climatic conditions from the Armavir and Ararat regions, whereas the climatic conditions and grape growing practices in Ararat and Armavir regions are quite similar, which means that the results of this study can be extrapolated to Ararat region as well.

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